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VULCANISATION EXPERIMENTS ON PLANTATION PARA RUBBER

(*The cause of variability.*)

BY B. J. EATON & J. GRANTHAM.

During the last two or three years much has been written and many statements made concerning variation in plantation Para rubber. The opinions expressed generally by manufacturers are to the effect that variation is considerable even in the case of "First latex" rubbers when compared with Fine Hard Para as the highest or first grade of wild Para rubber.

On the other hand leading rubber technologists and chemists have maintained that the best grades of plantation Para rubber—especially sheet, are superior to Fine Hard Para.

Both opinions may be taken as correct, as we shall show, and are not necessarily contradictory. Unfortunately neither the statements made by manufacturers nor the published results of experiments carried out by rubber chemists, have indicated the nature of this variation, still less have any published results enabled us to attribute this variation to any definite cause.

It has been assumed generally that variation refers to differences in the mechanical properties of the raw or vulcanised rubber, *i.e.* strength, elasticity, etc.

In our experience this is only true to a limited extent among "First latex" rubbers and represents only a part and by no means the principal part of such variation, as our experiments will show.

Our experiments have so far been confined almost entirely to "First latex" rubbers, but results obtained from a few samples of

lower grades appear to indicate that among these there is in addition a much larger variation in mechanical properties.

The experiments described in this paper give the first results obtained in the experimental vulcanising and testing laboratory at the Agricultural Department, apart from tests carried out on a number of estate samples which, at this early stage, have little value from a research point of view except that they show that considerable variation occurs amongst estate rubbers from first latex. Many other experiments have been commenced and are partly completed. The results will be published from time to time in the *Agricultural Bulletin* and will be collected later and published in the form of a special bulletin, when it will be possible to give greater detail and to illustrate the results by means of curves and diagrams which are much more instructive even than the figures given here, since the curves indicate the behaviour of the rubber throughout a test from the initial stretch to breaking point. These experimental results are the first, as far as the writers are aware, which have indicated the most important variation in plantation Para rubber, namely, its variable vulcanising capacity.

Previous Work by Other Experimenters.

Before giving the results of our experiments we wish to draw attention to previously published work on this subject.

Since these experiments were commenced and almost completed, an important paper, which has just come to hand, has been published by Fol.,* giving the results of vulcanising tests carried out on 137 samples of "First latex" plantation Para rubbers collected in London, Antwerp, Amsterdam and Rotterdam (A review and criticism of this paper will appear in the next *Agricultural Bulletin*).

The results given in this paper are interesting as shewing considerable variation in plantation rubbers under the conditions of vulcanisation employed, but give no indication of the cause of variation and unfortunately the experimenter has been obliged, as he states, to vulcanise all his samples for one particular time and temperature so that the variations which might have been shewn in respect to vulcanising capacity, are not apparent.

It is obvious however, to those who have had experience in vulcanisation, that some of the samples have been over vulcanised and others under-vulcanised which prevents any real conclusions being drawn.

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* Note:—Paper read by Fol at the International Rubber Congress, Batavia, October, 1914 and published in Report of the Congress.

In a discussion on variability in plantation rubber at the Third International Congress of Tropical Agriculture held in London in 1914, published in the "Proceedings" which has just been received, certain statements made by Mr. Williams, General Works Superintendent of the North British Rubber Company Edinburgh, are, as far as we are aware, the first opinions expressed by a manufacturer or rubber technologist which have a direct bearing on this problem of variation in the respect indicated by our experiments, but Mr. Williams is obviously not in a position to indicate the cause of the variations.

Three definite cases are quoted by Mr. Williams from recent factory experience as follows:—"The first case is one where we "were manufacturing moulded goods and the heat varied from 60 "minutes at 50 lbs. to 70 minutes at 50 lbs. a variation of 16·6 "per cent. The next case was one of open steam cure where the "variation was from 2½ hours at 270° F to 3½ hours at 270° F a "variation of 40 per cent. In the third case where we were dealing "with wrapped goods, open heated, the heat had to be changed "from 40 minutes at 50 lbs. to 80 minutes at 50 lbs. a variation "of 100 per cent."

In these remarks it will be observed that Mr. Williams says nothing as to variation in strength, elasticity or other mechanical properties of the vulcanised rubbers, but refers to the variation in the behaviour of the rubber during vulcanisation *i.e.* its vulcanising capacity.

In order to obtain certain definite results or qualities in making particular classes of goods from different batches of plantation Para rubber it was found necessary to alter the conditions of vulcanisation as shewn above.

In a second paper by the same author entitled "Plantation Rubber from the rubber manufacturer's point of view" published in the handbook "Rubber, Cotton, Fibre, etc." compiled and edited by Mr. Staines Manders as organiser of the Fourth International Rubber and Allied Trades' Exhibition held in London in 1914, which has also just come to hand, the following remarks occur:—

"My experience is, that quite apart from all questions of "strength, the question of the vulcanising properties of plantation "rubber is the greatest trouble the manufacturer has to face. "Without efficient control, faulty vulcanisation undoubtedly will be "responsible for loss of time and money. These troubles, in "factories where scientific control is not thoroughly organised, may "be sufficient to condemn the use of this grade entirely."

This statement is, in our opinion, a very important one, and, as our experiments will show, is the crux of the whole problem.

Hitherto manufacturers have complained of variability, but have made no statements indicating its nature, so that the general assumption has been that this variation is in the mechanical properties of the rubber alone, which as we shall show is quite erroneous.

Naturally the manufacturer is unable to trace the cause of this variable vulcanising capacity and the same applies to any rubber technologist working in Europe, unless he knows the exact details used in the preparation of the raw rubber and it was by knowing the complete history of our samples from latex to vulcanised rubber that we were able to elucidate one if not the only cause of variation in plantation rubber in respect to its vulcanising capacity.

Having ascertained the factor or factors causing this variability, the production of uniformity becomes much simpler, provided this factor is capable of being controlled, a problem we are now attacking.

The possible causes of variation both natural and artificial have been stated by Whitby and Morgan and by one of us, but no figures have been published showing the operation of any one factor, especially in this respect, *i.e.* its effect on the rate of cure or vulcanising capacity of the rubber.

Unfortunately the large number of results obtained by Messrs. Beadle and Stevens and published in Morgan's book "The preparation of Plantation Rubber," instructive as they may be to the experimenters themselves, are valueless to other workers on the subject and valueless to planters or manufacturers in the form in which they are published.

It is impossible to say whether these figures were obtained by vulcanising all the samples for the same time and temperature in which case they would have little or no value, since some samples may have been correctly cured and others over or under-cured; on the other hand if obtained under the conditions of optimum cure for each sample, no figures are given as to the rate of cure, which would indicate this important variation in vulcanising capacity, still less connect it with any particular mode of coagulation or preparation of the raw material.

Following this destructive criticism we will now describe some of our experiments and results and show (i) that plantation rubbers are very variable but that this variation is principally one of rate of cure and not of mechanical properties, since similar mechanical properties can be obtained in the vulcanised material, provided the correct rate of cure of the rubber under specified conditions is known. (ii) that this variation in rate of cure or

vulcanising capacity is due to some substance existing in the latex, or formed subsequently which, in the prepared raw rubber, acts catalytically as an accelerator and that the rate of cure of the raw rubber depends on the amount of this substance remaining in the raw rubber, which again depends on the mode of coagulation or preparation.

Experiments at the F. M. S. Testing Laboratory.

Before giving the results of our experiments it will be preferable, perhaps, to state the conditions under which the rubbers were vulcanised and to make a few remarks in connection with this part of the investigation, so that it will be possible for other workers to criticize these methods.

Mixing:—In each case the mixing used consisted of 90 parts of raw rubber and 10 parts of sulphur *i.e.* 10 per cent of sulphur calculated on the mixture. A mixture consisting of 450 grammes of rubber and 50 grammes of sulphur was found to be sufficient generally for each experiment.

After many preliminary experiments and failures through causes, which it is unnecessary to enumerate here, the following technique has been adopted. The rubber is rendered somewhat plastic on the hot mixing rolls and the sulphur sprinkled on by means of a small tin with perforations in the cover, similar to a pepper pot, and the mixing carried on till the mass is homogeneous and sufficiently plastic to run well on the calender. Such a mixture takes about 20 to 25 minutes to complete. At first, owing to faulty engineering details it was very difficult to keep the rollers sufficiently cool or to cool them down rapidly after each mixing, so that only one or two mixings could be carried out during the morning. We have however remedied this defect and are now able to mix about two samples per hour.

A few rubbers, as is well known, were found to require longer mixing and hotter rolls to render the mixture sufficiently plastic to calender. Low grade rubbers, on the other hand, require much cooler rolls.

Experiments on the effect of overworking on the mixing rolls have been carried out and we found that, unless excessively overworked or overheated, the differences between different mixes of the same rubber were not great. (These experiments and others in connection with the technique of the process will be described later in greater detail.)

Calendering:—The mixing was calendered to such a thickness that three folds of the calendered sheet gave a suitable thickness (just over 5 mm.) for making vulcanised slabs 5 mm. thick.

Calendered sheets of this thickness, when properly prepared, did not develop any faults such as air bubbles.

Moulds:—The moulds eventually adopted for vulcanising the samples, after numerous trials of various types had been made, were constructed as follows:—

A rectangular steel frame exactly 5 mm. thick was divided by means of two cross pieces into four rectangular compartments of equal size, each compartment being sufficiently large for a slab of vulcanised material from which two rings could be cut by means of the Schopper cutting press employed for cutting the test pieces. In this way, either four samples of different rubbers could be vulcanised in the same frame, or by removing one or both of the cross pieces, slabs large enough for 4 or 8 rings of the same material could be vulcanised. The outer side of each compartment was provided with a small opening made by a half-cut, to allow the excess of rubber to spue out. If this is not provided, the slabs are very uneven in thickness, an important point when comparing the stretch curves.

It was found by experiment that each compartment held about 40 grammes of the mixing and an amount slightly in excess of this was carefully weighed out by cutting the folded calendered sheet.

The frames are placed between two thick outer plates, ¾ inch thick, slightly larger in area than the frame and bolted together by means of ¾ inch bolts, in slots, for ease in fixing and removing.

The outer plates were heated in the steam autoclave, before the rubber was placed in the frames, so that the rubber was softened and could be more easily pressed in the frames. Between the surfaces of the rubber and the outer plates a layer of tracing cloth was used to prevent the rubber adhering to the mould and to prevent faults, such as "lakes," which were found to be formed when the rubber was in direct contact with the mould.

These precautions and details were ascertained after numerous experiments with various substances and repeated failures. A sheet of aluminium is said to serve the same purpose and can be used repeatedly, whereas the tracing cloth can only be used once; none however was available for our experiments.

Vulcanisation:—In the earlier experiments a temperature of 135° C was employed for vulcanisation, the apparatus used being a steam autoclave provided with a steam casing, the temperature being controlled by means of an accurate thermometer and a pressure gauge.

Some samples were found to take five hours or longer to vulcanise correctly at this temperature and as this was considered to be too long for the large number of experiments to be conducted

on each sample, the temperature adopted subsequently and employed in all the experiments described in this paper was 140° C.

It was soon discovered that to adopt both a standard temperature and time of vulcanisation was absurd. This was shown especially in connection with some very rapidly curing samples prepared by one of us, in which, had we adopted what may be described as a more average time of cure for plantations rubbers at this temperature, these samples would have been absolutely overcured and brittle. A series of cures was therefore carried out on each sample in which the time varied from about 1 to 3 hours. So far, no samples, at this particular temperature (140° C) have been found to cure under one hour and only one or two slightly over 3 hours. Although at first intervals of $\frac{1}{4}$ hour were taken, that is each sample was vulcanised at 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$ and 3 hours it has now been found that many of these times, after one preliminary cure, may be omitted, since the correct rate of cure can be predicted approximately from the results obtained from the preliminary cure and it is then only necessary to carry out one or two cures in the neighbourhood of this optimum time in order to obtain the maximum mechanical properties at this cure.

Testing:—All the tests described in this paper were obtained on the Schopper testing machine, which was provided with an autographic apparatus, so that the behaviour of the rubber throughout the whole test is recorded by means of a curve.

Test rings were prepared from the vulcanised slabs by means of the Schopper cutting press. The thickness and width of each ring was ascertained and the load per sq. mm. calculated from the cross sectional area, the ring being considered as equivalent to two strips *i.e.* a ring 4 mm. x 5 mm. being considered to have a cross sectional area of 40 sq. mm.

The load at breaking point was found to increase with the time of cure to a certain point and then to collapse, the rubber becoming very brittle at an overcure. The elongation decreases continually and fairly regularly with the time of cure until an overcure is reached when it falls rapidly. The maximum load is often only obtained when the rubber is obviously overcured *i.e.* it has become somewhat brittle and the extension is low. It is therefore somewhat difficult to fix the exact maximum point or point of optimum cure.

We have always taken as the optimum that point at which the product of the breaking load per unit cross section and the elongation is a maximum. Nearly every sample has a sharply marked maximum product, and any gain in load due to extra curing is

outweighed by a correspondingly greater fall in the extension and *vice versa*.

As we shall show later however in this paper the optimum cure is by no means essential in drawing conclusions from our results.

In determining the optimum cure the curves obtained on the Schopper testing machine are of great value. We understand that Dr. Schidrowitz has obtained a mathematical formula by means of which the optimum cure can be calculated from a preliminary test so that it is only necessary to carry out one subsequent cure—the optimum—in order to obtain the mechanical properties of the rubber at this point. Our attempts in this direction have been unsuccessful, but the value of the experience and the confirmation of results obtained in carrying out a series of cures on each sample, makes this a matter of little importance at this stage of our research. As it is impossible to reproduce here the curves obtained by tests on samples cured at different times, their value in this respect cannot be made apparent.

In connection with the time and temperature conditions of the vulcanisation, we may state here that by increasing the temperature of the cure, vulcanisation can be carried out in a shorter time (this shows the necessity of accurate control of the temperature and for this purpose we propose to attach a temperature and time controller to the autoclave; at the present time a native operator watches during the whole operation, under our supervision, and considerable care has to be taken to ensure constancy of temperature) similarly by carrying out the cure at a lower temperature, of cure a longer time is required to obtain the same mechanical properties in the vulcanised material.

For research purposes it is probably advisable not to vulcanise at too high a temperature, since at the lower temperature, especially with rapidly curing samples, a much greater margin of error in respect to time can be allowed, as the limit of time between under and overcured samples is much increased.

The relation between time and temperature of vulcanisation is probably complex but need not concern us here, as it concerns the manufacturer in making different classes of goods.

Experimental Results.

The experimental results to be described in this paper are derived from samples of rubber prepared by us at the Agricultural Department Factory, and include also a number of estate samples and samples of Fine Hard Para for comparison.

The estate samples, as will be seen from the tables, demonstrate clearly that the variation, to which we have referred, in respect to

rate of cure or vulcanising capacity occurs not only among "first latex" rubbers from different estates but among samples from the same estate. Our conclusions however as to the cause of this variation are based on our own samples, the complete history of which was known; the investigation has not been carried sufficiently far to enable us to attribute the variation in estate samples to any one factor since more than one factor may be concerned, which may be either natural or artificial or both. The mode of preparation of the estate samples was usually unknown and several variables may have been introduced. Our experimental samples, however, have shewn us one very important cause of variation in respect to rate of cure and we have reason to believe that the variation in all samples is due to the same ultimate cause, although differences in method of coagulation and preparation and other factors contribute to this cause. This factor is of considerable importance to the manufacturer, and capable probably of being controlled and applied to good purpose. Many results, which were at first difficult to understand, have now become capable of explanation and support the theory, which we shall enunciate here. Other experiments are indicated in the paper, by means of which we hope to carry the investigation a step further. These results also, especially when one compares them with the general appearance etc. of the raw rubbers tested, demonstrate the absolute absurdity of the present methods of market valuation.

Historical:—It will be preferable perhaps to develop the theory chronologically in respect to the experiments conducted by us.

In carrying out the vulcanisation of a number of samples of smoked sheet and plain crepes prepared in the Agricultural Department factory from latex which was reduced to a standard density of about 0·9910 corresponding to 15 per cent or 1.5 lbs. of dry rubber per gallon, the optimum results from tests on the vulcanised samples were obtained by curing the samples at about 2¾ to 3 hours. The results for a few of the samples are given in Table 1.

TABLE I.

SMOKED SHEET AND PLAIN CREPE.

Type of rubber.	Ref. number.	Time of cure Hr. min.	Load kgs. per sq. mm. (a)	Final length (original length-100) (b)	Product (a & b)
Plain crepe	21 A 1	1.20	0.45	1168	525
		2.00	0.9	1127	1014
		2.30	1.1	1020	1122

Type of rubber.	Ref. number.	Time of cure Hr. min.	Load kgs. per sq. mm. (a)	Final length (original length-100) (b)	Product (a & b)
		2.45	1.35	1002	1352
		3.00	1.45	980	1421
		3.15	1.25	910	1137
Plain crepe	21 A 3	1.20	0.35	1116	391
		2.00	1.15	1089	1252
		2.30	1.3	1034	1344
		2.45	1.5	1016	1524
		3.00	1.45	961	1393
		3.15	1.2	893	1071
		4.00	0.25	373	93
Smoked sheet	28 A	1.45	0.64	1069	684
		2.00	0.75	1056	792
		2.15	0.88	1046	920
		2.30	1.1	1020	1122
		2.45	1.35	1010	1363
		3.00	1.60	1009	1614
		3.15	1.33	946	1258

The above results are the maxima obtained from 2 to 4 test rings at each time and are typical of the majority of our smoked sheets and plain crepes. The results have been confirmed by numerous experiments and our conclusions are not based on the examination of a single specimen. The figures immediately above the line, in each case, represent the optimum time of cure and the optimum product obtained at this cure. Figures below these lines indicate an overcure. This applies also to the tables which follow.

It was difficult from the results obtained in our earlier work on the above and similar samples to attribute a difference in time of cure of about ¼ hour to any particular factor.

Subsequently a sample of "Byrne cured slab" was received for examination and this was found to cure in the remarkably rapid time, under similar conditions as to temperature and mixing, of 1¼ hours, a difference sufficient to demonstrate the influence of some very important cause of variation.

The results obtained are given in Table II which follows:—

TABLE II.

Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig length-100) (b)	Product (a & b)
VIII A	30	0.5	1125	562
	45	0.67	1172	718
	1.00	1.1	1057	1163
	1.15	1.46	1070	1563
	1.30	1.4	993	1390
	2.0	0.45	668	301
	2.30	0.28	488	136

Slabs which had been prepared by one of us from latex of density 0.9910 at the Agricultural Department and smoked in a Byrne smoking shed erected at the Department, using a machine which had been kindly lent to us by the Byrne Curing Syndicate for experiments on this process and for demonstration purposes, were now tested. These slabs also vulcanised rapidly, as will be seen on reference to Table II. A.

TABLE II. A.

BYRNE CURED SLABS.

Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig length-100) (b)	Product (a & b)
38 A.	1.15	1.11	1086	1125
	1.30	1.43	978	1398
	1.45	1.22	903	1102
	2.0	0.92	807	742
	2.30	0.16	387	63
38 B.	1.15	1.16	1064	1234
	1.30	1.27	1000	1270
	1.45	1.22	908	1100
	2.0	0.82	797	653
	2.45	0.13	325	42
38 C.	1.15	1.19	1055	1255
	1.30	1.27	1029	1306
	1.45	1.37	950	1301

Ref. number	Time of cure Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product (a & b)
	2.0	1.22	890	1085
	2.45	0.17	388	66
38 D.	1.15	1.31	997	1306
	1.30	1.44	984	1416
	1.45	0.50	716	358
	2.0	0.22	507	111
	2.45	0.15	353	52

The next problem was to ascertain whether this rapidity of cure was due to any constituent of the "Byrne" fumes or to the form in which the rubber was prepared.

Samples of Byrne "loaf" had been prepared by one of us about this time and were vulcanised and tested. (As is probably well known this consists of sheet of ordinary thickness cured by means of the Byrne process and subsequently rolled round a stick or bamboo, superimposing other sheets till a solid cylinder of rubber is obtained. By putting a little tension on the sheets when wrapping them round the stick, the sheets adhere and the solid cylinder when cut open is seen to consist of alternate light and dark layers—the light layers representing the interior of the sheets and the dark layers the surfaces.) This rubber, like slab and Fine Hard Para, never completely dries in the original form and has to be creped and dried before vulcanising.

The results of the tests on the vulcanised samples are given in Table III, sample A being the ordinary form of loaf and sample B pressed block from similar sheets.

TABLE III.

Type	Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product. (a & b)
"Loaf"	34 A	1.45	1.12	1078	1207
		2.15	1.2	1051	1261
		2.30	1.3	1026	1323
		2.45	1.45	986	1430
Pressed sheet	34 B	1.45	0.98	1090	1068
		2.0	1.0	1037	1037
		2.15	1.26	1028	1295
		2.30	1.35	1015	1373
		2.45	1.44	999	1438
		3.0	0.25	572	143

The optimum cure in the above table is seen to be at $2\frac{3}{4}$ hours, which is the same as the smoked sheet in Table I and quite different to the slab.

The results point to the fact that the rapidity of cure in the case of the Byrne cured slab in Table II and II A is not due to the Byrne fumes.

Another sample of rubber prepared by coagulating latex in thin layers in shallow trays in a smoke house, and superimposing further layers daily for a period of about one week was also found to vulcanise rapidly. (This method of coagulation has been described by one of us in papers presented to the International Congress of Tropical Agriculture London 1914 and the International Rubber Congress Batavia 1914 etc.)

The results of this experiment are given in Table IV.

TABLE IV.

Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product (a & b)
31 D.	1.0	0.68	1100	748
	1.15			
	1.30	1.26	1093	1377
	1.45	1.07	1018	1089
	2.0	0.80	910	728
	2.30	0.25	563	126
	3.0	0.23	586	134
31 E.	1.0	0.83	1147	952
	1.15			
	1.30	1.31	1108	1451
	1.45	1.13	1041	1169
	2.0	1.18	979	1155
	2.30	0.24	560	134
	3.0	0.26	519	134

Unfortunately the quantity of the samples was insufficient to allow of a cure being done at $1\frac{1}{4}$ hours but the above results clearly show that the rubber is a very rapidly curing one.

The results given in this table confirm the idea that the rapidity of cure was not due to any intrinsic properties of the "Byrne" fumes and suggested that it was connected with the slab form in which the rubber was prepared.

Another experiment which was being carried out about this time was a comparison between smoked and unsmoked sheet in

which it was noticed that the smoked sheet vulcanised more slowly than the plain sheet, the former having its optimum cure about 3 hours and the latter at 2½ hours.

A second and more elaborate experiment, in which comparison was being made between smoked sheet, unsmoked sheet and plain crepe, was also in progress. Here again the smoked sheet and the crepe were slower curing than the unsmoked; the results were identical for batches of rubber prepared on seven different days, but the relation between the smoked sheet and crepe varied, sometimes one and sometimes the other being the more rapid curing. The differences are more apparent when examining the curves showing the behaviour of the rubber throughout the test, the unsmoked sheet invariably curing more rapidly than the others.

The results of the first day's batch of rubber are given in

TABLE V.

Type of Rubber	Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product (a & b)
Smoked sheet	27 Series I A.	1.30	0.59	1067	629
		1.45	0.84	1086	914
		2.0	1.03	1053	1084
		2.15	1.27	1058	1344
		2.30	1.40	1041	1457
		2.45	1.42	1009	1433
		3.0	1.26	848	1214
Plain crepe	27 Series I C.	1.30	0.9	1110	999
		1.45	0.92	1087	1000
		2.0	1.21	1047	1266
		2.15	1.4	1046	1464
		2.30	1.40	996	1394
		2.45	1.5	972	1438
		3.00	1.48	937	1386
Plain sheet	27 Series I B.	1.30	1.12	1070	1198
		*1.45			
		2.0	1.59	1021	1613
		2.15	1.50	1000	1500
		2.30	1.44	957	1378
		2.45	1.1	855	940
		3.0	0.27	553	15

* Sample exhausted.

In the case of the plain crepe results we have a difficulty in deciding which time shall be considered the optimum. This is a rubber which gives excellent results at all times between 2¼ and 3 hours. It is quite clear however that the unsmoked sheet cures more rapidly than either the crepe or the smoked sheet. It attains its maximum load in a shorter time viz. 2 hours as compared with 2¾ hours in the case of the smoked sheet and crepe. Also, it will be noted the collapse in load and extension denoting a marked over-cure is reached by the unsmoked sheet at 3 hours whereas this has not been reached by the smoked sheet and crepe.

These results indicate that smoking retards the rate of cure. We now have the following facts concerning the variation in rate of cure.

(1). Slab rubber smoked with Byrne fumes or rubber coagulated by smoke, by superimposing layers of latex, cures much more rapidly than plain crepe or smoked sheet.

(2). Unsmoked sheet cures more rapidly than smoked sheet or plain crepe.

In continuation of the first idea, connected with the slab form of rubber, the following series of samples were prepared, in each case from the same latex.

Latex was coagulated in bulk in a wood box divided by means of movable partitions, so that each section of the coagulum received identical treatment in respect to coagulation. The coagulum from each section was removed on the following morning and treated subsequently as follows.

(1). Two slabs about ½ inch thick were made by rolling the coagulum lightly with a hand roller.

(2). Two sheets of ordinary average thickness were prepared from two other sections of the box, by rolling out on an ordinary sheeting machine.

One of the slabs from (1) was allowed to air dry and the other placed in the smoke house and similar treatment was accorded the two sheet from (2). The rubbers were allowed to remain in the drying house and smoke house respectively till the sheets from (2) were dry.

The slabs had to be creped subsequently before vulcanising; the sheets were also divided into two, and half was mixed direct and half creped before mixing so that the following series of samples were obtained.

(i) Smoked slab creped. (ii) Air-dried slab creped. (iii) Smoked sheet. (iv) Ditto creped when dry. (v) Plain sheet. (vi) Ditto creped when dry.

The vulcanised samples were tested and entirely confirmed the theory to be enunciated later which had been indicated by the previous samples of slab and other rapidly vulcanising rubber.

Although in Table VI, which follows, we have given only the results of one day's experiment in order not to have too many figures, this experiment, like all our experiments, has been carried out on different days over a period of 8 or 10 days and the results obtained for each day's batch are similar.

TABLE VI.

Ref. number	Type of Rubber	Time of cure. Hrs. min.	Load kgs. per sq. mm.	Final length (orig. length-100)	Product
			(a)	(b)	(a & b)
37 series 5 (A).	Smoked sheet.	1.30	.83	1110	921
		1.45	.90	1075	967
		2.00	1.12	1048	1174
		2.15	1.32	1023	1350
		2.30	1.31	988	1294
		2.45	1.5	961	1443
		3.	1.46	938	1370
37 series (A).	I. Smoked sheet, creped when dry.	1.30	.83	1097	910
		1.45	.87	1091	949
		2.00	1.02	1043	1064
		2.15	1.15	999	1148
		2.30	1.35	1008	1361
		2.45	1.47	958	1408
		3.	1.47	944	1387
37 series 5 (B).	Smoked slab.	1.00	1.06	1115	1182
		1.15	1.17	1084	1268
		1.30	1.45	1038	1505
		1.45	1.51	1009	1523
		2.	1.32	912	1204
37 series 5 (C).	Unsmoked Sheet.	1.30	.74	1094	819
		1.45	.88	1086	957
		2.00	1.02	1037	1058
		2.15	1.14	1006	1146
		2.30	1.17	975	1141

Ref. number	Type of Rubber	Time of cure. Hrs. min.	Load kgs. per sq. mm.	Final length (orig. length-100)	Product
			(a)	(b)	(a & b)
		2.45	1.5	948	1423
		3.	1.37	915	1253
37 series 5 (C). I	Unsmoked	1.30	.78	1122	875
	sheet, creped	1.45	.88	1108	975
	after drying.	2.00	1.00	1052	1052
		2.15	1.17	1024	1198
		2.30	1.25	990	1237
		2.45	1.5	963	1444
		3.	1.46	954	1383
37 series 5 (D).	Unsmoked slab	1.00	1.36	1064	1447
		1.15	1.41	1024	1444
		1.30	1.44	952	1360
		1.45	1.38	921	1270
		2.00	.34	600	204

The conclusions to be drawn from the above table are:—

(1). Crepeing of dry sheet previous to mixing has no effect on the vulcanising properties of the rubber.

(2). Slab rubber cures very much more rapidly than sheet.

(3). The effect of smoking on the slab rubber is to retard vulcanisation.

In a previous experiment (Table V) it was seen that unsmoked sheet rubber cured more rapidly than smoked, and this effect was noticed in seven different days' rubber.

At first sight then it seemed difficult to explain why no difference was apparent between the smoked and unsmoked sheet in this experiment. On examining the sheets the cause became apparent. The sheets in this experiment were abnormally thin and thus a rubber was obtained in which there remained only a minimum amount of the serum.

In view of the theory given later, it will be seen that this fact would tend to eliminate the difference in rate of vulcanisation between smoked and unsmoked rubber. In this connection it is also interesting to note that the only sample of smoked crepe which has been tested by us gave its optimum cure at 2¾ hours, which is the normal time for ordinary crepe rubbers.

These results clearly show the different vulcanising properties of slab and sheet. The effect of smoking on slab rubber is also well marked.

Cause of Variation.

It will be observed from the tables given that the rapidly curing samples are those prepared in slab form or by smoke coagulation of latex in shallow pans. Now the only difference between these samples and sheet and crepe is the amount of serum or mother liquor remaining in the samples after preparation. Slab has only a small proportion of serum pressed out by hand rolling compared with the amount pressed out in rolling thin sheets. In the smoke coagulated rubber also, a large proportion of the serum remains in the prepared rubber.

Two alternative explanations of these facts suggest themselves.—(1) that the latex contains, in addition to the caoutchouc, some constituent which influences the rate of cure of the rubber, this substance not being precipitated by ordinary coagulation. Consequently the greater the quantity of the serum remaining in the rubber, the greater will be the quantity of this substance present in the raw rubber. If this be the case the effect of smoking is apparently to destroy the substance. (2) It may be however that this substance does not exist as such in the latex but is formed subsequently from some constituent of the latex. In this case the retention of the serum in the rubber would appear to encourage the formation of the catalytic substance.

By the ordinary methods of chemical analysis of raw rubber, which are somewhat crude, the non-caoutchouc substances present in latex are classified as proteins or organic nitrogenous substances, resins, carbohydrates and mineral salts.

In the first place the protein is calculated from the total nitrogen content on the assumption that all the nitrogen is present in this form, which may be quite erroneous.

Whether the rate of cure is influenced by the proteins, as such, or to any of the other constituents enumerated above, remains to be investigated.

It is already known that certain organic amines and basic nitrogenous substances *e.g.* piperidine, have a remarkable influence in accelerating the rate of cure or vulcanisation of rubber and a number of substances containing such compounds have been patented and are on the market.

Beadle and Stevens have also shown the influence of albuminous substances on vulcanisation, but the experiments, as published, were not carried sufficiently far.

It is possible then, and this upholds the second of the two explanations which we have just enunciated, that decomposition of the proteins of the latex takes place with formation of amine substances which accelerate the rate of cure and the greater the amount of serum left in the rubber the more favourable the conditions for this decomposition. This view is confirmed by the slow curing which we have observed in the case of rubbers prepared from latex treated with preservatives (vide estate samples Table VIII) and also by the lengthened cure consequent upon smoking, which also acts as a preservative. Further experiments on this point are being carried out and are enumerated later.

It may be however that the problem is much more subtle and that some substance is present, possibly produced by the action of an enzyme, which is not revealed by the ordinary methods of chemical analysis and that smoking has the effect of destroying the substance.

Whichever of the two theories proves to be correct, we have finally in the raw rubber some substance of a catalytic nature capable of profoundly modifying the vulcanising properties of the rubber. (This explains the difficulty of vulcanising synthetic rubber and instances another case, analogous to that of steel, in which absolute purity is unnecessary and undesirable.)

It is hoped that the experiments now in progress will elucidate the exact nature of this substance. It would appear not to be easily destroyed by heat, since both in the mixing and subsequent vulcanisation process the rubber is subjected to a considerable temperature. During washing and rolling of freshly coagulated rubber this substance is either removed or its formation prevented by the removal of something essential to its formation. In this connection the slow vulcanisation of some excessively thin crepes (Table VIII Samples II E & F) will be noted.

Once however the serum has been allowed to evaporate from the rubber, as in the case of sheets and slabs, subsequent crepeing has no effect.

The action of smoke in destroying or preventing the formation of the substance is more complete in the case of sheet than of slab, the former being smoked throughout while the latter is only affected on the surface. As a consequence smoked slab cures more rapidly than smoked sheet.

With regard to the rubber prepared by smoking layers of latex in shallow trays, this again is only subjected to the action of smoke on or near the surface of each layer. Unsmoked or air dried slab gives the most rapidly curing rubber we have prepared, on account

of (i) the large amount of serum which remains in the rubber and (ii) the absence of smoking.

In the case of Fine Hard Para the action of smoke is well seen. This rubber, containing as it does all the constituents of the latex, might have been expected to cure rapidly. It is however prepared in such a manner that the smoke exerts its maximum effect and Fine Hard is relatively slow curing.

FINE HARD PARA.

Although up to the present, only five samples of Fine Hard Para have been vulcanised and tested (four of these samples were kindly sent to us by the Planters' Stores & Agency Ltd., Kuala Lumpur and by Messrs. Thompson Bros. of Mincing Lane), these have shown much more uniformity in respect to rate of cure, when considered as the first grade of wild rubber, than first grade plantation Para rubbers. It should be noted however that while there is only one class of Fine Hard Para, prepared by one method, there are numerous classes of first grade plantation Para rubber.

The results of tests on vulcanised specimens of Fine Hard Para are given in Table VII.

TABLE VII.

FINE HARD PARA.

Ref. number	Time of cure. Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product (a & b)
23.	1.0	0.55	1130	621
	1.30	0.78	1100	869
	2.0	0.72	1000	720
	2.30	1.25	1058	1322
	2.45	1.15	1006	1156
24.	1.0	0.58	1094	632
	1.30	0.95	1105	1050
	2.0	1.07	1041	1114
	2.30	1.36	1027	1396
	2.45	1.26	980	1234
	3.0	1.05	921	966
25.	1.0	0.63	1108	698
	2.0	1.08	1061	1145
	2.30	1.38	1026	1414
	2.45	1.52	1034	1571
	3.0	1.39	1000	1390

Ref. number	Time of cure Hrs. min.	Load kgs. per sq. mm. (a)	Final length (orig. length-100) (b)	Product (a & b)
	3.20	1.35	951	1283
29.	1.0	0.53	1140	604
	2.0	0.91	1067	971
	2.30	1.17	1057	1236
	2.45	1.34	1044	1399
	3.0	1.26	999	1259
16.	1.0	0.31	1085	336
	1.30	0.58	1082	628
	2.0	0.78	1013	790
	2.15	0.99	1034	1023
	2.30	1.14	994	1133
	2.45	1.08	957	1033
	3.0	0.82	894	696

Sample 16 was a very old sample which had been at the Agricultural Department since 1906 or 1907. As will be seen the time of cure is fairly constant at 2½ to 2¾ hours. Further samples have been received and will be tested. As regards the mechanical properties, Nos. 23, 24, and 29 are fairly good, though below most of our own experimental samples. No. 25 is very good, but again not equal to our best experimental samples.

These results are in accordance with the views of manufacturers on its uniformity and to the statements of rubber technologists to the effect that the mechanical properties of some plantation Para rubbers after vulcanisation are superior. Uniformity in rate of cure is relatively of much greater importance to the manufacturer.

Possibly however the time which has elapsed between preparation and vulcanisation is the cause of this slight inferiority. This is cofirmed by the inferior results of No. 16 which is a very old sample. Experiments on the effect of keeping raw rubber are in progress, as most of our experimental samples were vulcanised and tested soon after preparation. On the other hand, some samples which have been kept for over a year have given good results.

Estate Samples.

To illustrate variation among estate samples tables VIII and VIIIA are included. Although we believe that the ultimate cause

of variation in rate of cure is the same in all cases *i.e.* it is dependent on the proportion of the catalyst in the rubber, the amount of this substance may depend on several factors connected with the mode of preparation *e.g.* dilution of latex, washing of rubber, thickness of rubber, smoking, rapidity of drying, presence of preservatives, amount of coagulant etc. and the exact factor causing the variation in the estate samples is unknown, as the mode of preparation and coagulation was not known by us.

TABLE VIII.

Estate Samples.

Ref. number	Type of Rubber	Optimum time of cure. Hrs. min.	Load Kgs. per sq. mm. (a)	Final length (orig length-100) (b)	Product (a & b)
Estate No. 1	B. Lump crepe.	2.45	1.31	994	1308
„	C. No. 1 Blanket crepe.	2.45	1.11	1019	1131
„	D. Smoked sheet (Bisulphite).	2.45	1.23	997	1229
„	E. Smoked sheet (Formalin).	3.15	1.26	961	1210
„	F. Smoked sheet (Bisulphite).	3.00	1.0	1035	1035
„	G. Smoked sheet.	2.45	1.14	965	1100
„	H. Smoked sheet.	2.45	1.4	950	1330
„	J. „ „	2.45	1.44	949	1366
„	K. „ „ (new coagulant).	2.45	1.44	949	1366
„	L. No. 1 Latex crepe.	3.00	0.9	973	875
„	M. No. 1 Lump crepe.	2.00	1.24	1003	1243
„	N. No. 2 Crepe (Best scrap).	2.30	1.2	919	1102
„	R. No. 2 Crepe (nat dried).	2.15	0.88	952	838
„	T. No. 2 Crepe (Colombo drier).	2.45	1.1	914	1005
„	P. No. 3 Bark scrap crepe (nat dried).	3.00	1.17	883	1033
„	S. No. 4 Bark				

Ref. number	Type of Ruber	Optimum time of cure Hrs. min.	Load kgs. per sq. m.m. (a)	Final length (orig. length-100) (b)	Product (a & b)
	scrap crepe (nat dried).	2.30	0.78	910	710
„	Q. No. 4 Bark scrap crepe (nat dried).	3.00	0.93	883	821
„	O. No. 4 Earth scrap.	2.45	0.62	915	567

In the above table the results at the optimum cure only are given. Samples B, C, D, E, F, Q, R, S, T were left for over a year before testing and the remainder G, H, J, K, L, M, N, O, F for about six months. The smoked sheets G, H and J were coagulated with acetic acid and prepared similarly, the latex being from different fields, K was coagulated by means of a new coagulant.

TABLE VIII A.

Ref. number	Type of Rubber	Optimum time of cure Hrs. min.	Load kgs. per sq. m.m. (a)	Final length (orig. length-100) (b)	Product (a & b)
Estate No. 2 A. Smoked sheet. (Very much overcured at 2½ hours)					
„	B. „ „	2.00	1.5	954	1431
„	C. „ „	1.45	1.32	982	1296
„	D. „ „	2.15	1.49	983	1464
„	E. Thin crepe.	3.15	1.3	940	1222
„	F. „ „	3.00	1.47	987	1451

With regard to the above, sample 2A was smoked for 20 days. It did not appear to be dry when received, and was creped before mixing. As there was no loss of weight after crepeing and drying the sample must have been dry but not smoked completely through. Sample 2 B had been smoked for 16 days and 2 C for 20 days. Sample 2 D was allowed to stand overnight after coagulation and smoked for 16 days. The thin crepes 2 E & F had dried in 14 and 20 days respectively.

A number of other estate samples have been examined but since they do not give times of cure beyond the limits given in Tables VIII and VIII A nor shew any other abnormalities, their publication here serves no purpose.

Notes on samples from Estate No. 1:—All the first quality samples were of good appearance. It will be noticed that among the "first latex" samples, the optimum time of cure, with four exceptions, is 2¾ hours.

Two of the smoked sheets which give longer cures were treated with formalin and sodium bisulphite respectively. As we have remarked before, the use of such agents appears to retard the rate of cure. The mechanical properties of the first latex samples from Estate No. 1 are all low in comparison with our experimental samples. This may be due to the length of time during which the samples had been kept, although, as we have stated before, all samples do not deteriorate on keeping to the same extent.

With regard to the lower grades it is at once apparent that not only does the time of cure vary but the mechanical properties at the optimum cure are also very inferior and variable.

Estate No. II. In the case of the samples from Estate No. II we have an instance of considerable variation in rate of cure, viz from 1¾ to 3 hours, although the mechanical properties at optimum cure do not exhibit marked differences. In this case we have not sufficient knowledge of the methods of preparation and origin of the rubber to be able to give the exact factor which has influenced the rate of cure. This is probably a typical example of the variability of which manufacturers complain and shows that this occurs among rubbers from the same estate as well as among rubbers from different estates.

Remarks on Results.

In these tables we have underlined the optimum times of cure in Tables I to VIII together with the mechanical properties obtained at this time. This optimum time is taken to be the time at which the figures in the tables under the heading "Product (a x b)" was a maximum. This figure, which is the product of the breaking load in kilogrammes per square millimetre and the final length of the sample, is proportional, as can be seen, to the breaking load of the specimen per square millimetre calculated on the cross section at breaking point, since this cross section is inversely proportional to the elongation of the sample. This figure however is by no means essential as the sole proof as to difference in cure, since similar conclusions can be drawn from all the figures taken collectively, and more especially from the curves showing the behaviour of the rubber throughout the test at all intermediate loads and elongations. Unfortunately however we are unable to produce curves here although they are much more instructive than the figures given in the tables which merely show the final load and elongation at break. (These curves will be reproduced later in a special bulletin and some typical curves given in a paper on this subject in one of the English technical journals.) By plotting the product figures against time the curves obtained also give an excellent idea of the differences in cure.

It will be seen on reference to these tables that to obtain similar mechanical properties in the vulcanised rubbers (taking the optimum cure) it was necessary to vulcanise the samples for periods varying from about 1 to 3¼ hours.

By taking five minute intervals in the times of cure, slightly more accurate results for the optimum cure would possibly be obtained; thus a sample in which the optimum time found was 2 hours, might be found to be five minutes or more under or above this time. This would however involve more tests and is not essential to the investigation.

As the tables show, there are differences in mechanical properties in the case of some "first latex" rubbers, as well as differences in rate of cure, but these are not so marked and are by no means of such vital importance to the manufacturer as the vulcanising capacity of the rubber. We are therefore dealing with two factors, one which influences the rate of cure of the rubber which as we have shewn is due to the presence of variable quantities of some unknown catalyst in the rubber and the other which influences the mechanical properties. The latter is probably connected with a decomposition of the caoutchouc molecule, oxidation products, resins etc.

Further Experiments in Progress.

The following experiments, which should throw further light on the problem, and enable us to ascertain the nature of this unknown catalyst are in progress.

(1). Preparation of a series of samples of rubber varying in thickness, so that the thicker samples contain more serum. These series will contain smoked and air dried samples.

(2). Evaporation of large quantities of the serum, after coagulation of the rubber. The residue will be dried and mixed with slow curing samples to ascertain its effect.

(3). Evaporation of similar serum in vacuo at a low temperature, in case evaporation at higher temperatures destroys the accelerating substance.

(4). Evaporation of thin layers of latex in a desiccator, so that all the constituents of the latex remain in the rubber and are not affected by smoke or other factors which may destroy the catalyst.

(5). A similar experiment to (4) but with addition of preservatives to the latex.

(6). Preparation of slab rubber with subsequent prolonged soaking in running water to see whether catalyst is removed by this method (*N.B.* The colloidal nature of the coagulum may destroy the value of this experiment).

(7). Addition of preservatives to latex with subsequent coagulation and preparation of slab etc. to ascertain whether such reagents prevent the formation of this catalytic agent.

(8). Isolation of any active principle affecting the rate of cure if the above experiments yield satisfactory results.

(9). Various experiments using different coagulants and addition of salts etc. to latex, which may produce rapidly curing rubber similar to slabs.

(10). Length of time during which slab is allowed to dry before crepeing.

The isolation of the active principle may involve considerable research and is perhaps of more academic than practical value; on the other hand its isolation and identification may prove of considerable importance.

The Problem of Uniformity.

We have shewn in the results given here, that lack of uniformity in rubber refers principally to non-uniformity in vulcanisation and it is only necessary to see the vulcanised specimens which have been prepared, to realize the manufacturers' dilemma when purchasing different lots of plantation rubber, as the appearance of the raw rubber, its mechanical properties as indicated by hand stretching and other crude tests applied on the market, colour etc., give absolutely no indication of this particular difference in behaviour on vulcanisation. If these rapidly curing samples, which should save the manufacturer a considerable amount in steam and heating costs, and in time and labour in the supervision of the steam autoclaves, presses etc., were placed on the market at the present time, they would probably fetch from 2*d* to 3*d* less than the market price of samples of smoked sheet and pale crepe having a pretty appearance, in spite of the fact that it would be to the manufacturer's advantage to pay perhaps 1*d* to 2*d* above the market value of the average first qualities for them. If we can combine appearance with real value, so much the better, but if not, the former will have to go, sooner or later, except for special purposes.

It is possible that the substance which causes this variation in rate of cure may be present in varying proportion in different latices or may be formed in different proportions subsequently owing to differences in original latices, in which case the problem of attaining uniformity becomes more difficult to solve. If, on the other hand, as appears more probable, the variation in the amount of this substance is brought about principally by artificial causes, such as different treatment in machining, washing and coagulation methods, it may and probably will be easier to introduce greater uniformity.

The differences hitherto ascribed to excessive machining of raw rubber are probably almost invariably due to the overwashing or tightness in rolling, by which crepes and sheets of different thicknesses are produced containing variable proportions of serum. There is probably a limit beyond which little or no further effect occurs, this is probably represented in the thin crepes curing at 3¼ hours, but may be brought about by methods other than washing.

If uniformity is unattainable by present factory methods and it will certainly be very difficult among rubbers from different estates, although not so difficult among the rubber from any particular estate, only two methods of dealing with the problem remain. (1) the issue of certificates showing the rates of cure of a shipment of rubber, under certain conditions (*N.B.* The manufacturer after a short time would be able to correlate his works' practice with the figures supplied) or (2) a method of preparation of rubber similar to that suggested by one of us viz. a method in which a block, ball or slab of rubber is prepared from latex day by day for a period of a week or longer, in order to average any variations.

We do not pretend in this paper to have solved the whole problem, but we do maintain that this discovery is a considerable step towards the attainment of the object in view, since it shews one, if not the only cause, of a variation of vital importance to the manufacturer. It remains to investigate the various contributory causes or factors which affect this, as we believe, ultimate cause. These contributory factors may be numerous and may be both artificial and natural. Having ascertained the cause, the application of a remedy is certainly less obscure.

We will now summarize the results obtained and the conclusions which these results have led us to deduce.

Summary of Results.

The results so far obtained may be summarized as follows:—

(1). Considerable variation occurs in plantation Para rubbers even in the case of "First latex" rubbers, both from rubbers from the same estates and from different estates.

(2). This variation is connected principally with the behaviour of the rubber on vulcanisation *i.e.* its rate of cure, and not in respect to its strength, elasticity and general mechanical properties, especially in the case of properly prepared "first latex" samples.

(3). If the rate of cure be known or ascertained under specific conditions, vulcanised rubber, having similar mechanical properties,

can be made from all good samples af " First Latex " rubbers.

(4). A difference in mechanical properties does exist, even among so-called first quality rubbers, but these differences are greater between high and low grade plantation rubbers; some rubbers never attain the maximum mechanical properties reached by others, whatever period of cure is adopted. These differences in the case of " first latex " rubbers however are not so important to the manufacturer as the differences in rate of cure, and are not of the same order.

(5). The rate of cure is due to the presence of some non-caoutchouc substance in the latex, possibly the proteins or some other constituent, or to some degradation product derived from these substances which acts as a catalyst and accelerates the rate of cure.

(6). This substance may be already present in the latex, and its amount in the raw rubber determined by the mode of preparation and coagulation, or it may be subsequently formed in the latex by decomposition, and taken up by the rubber in variable quantity according to mode of preparation, or alternatively it may be formed in the coagulum in variable quantity depending on the amount of serum (or moisture) left in the coagulum or the presence of preservatives which hinder or prevent its formation. The alternative theories await investigation.

(7). Smoking, removal of excess of serum (or moisture) in the washing and machining processes and preservatives are among the artificial factors which either hinder the formation of this substance or, if it already exists in the prepared rubber, partially destroy it. The natural differences in latex due to natural causes may also have a similar effect.

(8). The catalytic substance is probably not affected greatly by heat, since in the processes of mixing and vulcanisation, the rubber is subjected to considerable temperatures, although heat may prevent its formation in the latex or freshly coagulated rubber.

(9). The rate of cure of a rubber under specified conditions, is not indicated in any way by the apparent mechanical or any other apparent properties of the raw material, hence the absurdity of the present " methods " of valuation of rubber.

(10). Caeteris paribus, a manufacturer probably prefers a rapidly curing rubber, as it represents economy in heat, labour and time costs, and secondly, a rubber which cures rapidly is said to have better keeping qualities after vulcanisation. Rapidly curing samples should therefore obtain a premium in the market and probably would do, if valuation were carried out on a scientific basis, provided uniformity in rate of cure is maintained at the same time.

(11). Uniformity between "First latex" rubbers from different estates will probably be very difficult of attainment with present methods, owing to the number of factors involved, but should not be difficult of solution among such rubbers from the same estate.

(12). Two alternatives are suggested (1) the issue of certificates giving correct rate of cure and mechanical properties at this cure. (2) the attainment of more uniformity by the method suggested in this paper and elsewhere, in which rubber from latex collected during a series of days forms part of one ball or block, which may be described as the method of averages.

HOST PLANTS OF PINK DISEASE IN MALAYA.

By A. Sharples.

A list of plants growing in Malaya attacked by Pink disease is given in Bull. No. 21 issued by the Dept. of Agriculture, F. M. S. In this publication attention is directed to the large percentage of fruit trees included in the list. Further it is mentioned that Rant in Java has found this fungus on 141 species belonging to 104 genera of plants.

These figures indicate the omnivorous character of the fungus. In Malaya the plants grown, especially flowering plants, are not so diverse as in Java, and the number of hosts for Pink disease is therefore considerably less. With the continued introduction of plants from other countries we can expect an increase in the number which Pink disease will find suitable as hosts.

Three new hosts are to be added to the already published list for Malaya. They were obtained from the Govt. estate at Telok Anson during a recent visit.

(1). Tephrosia Hookeriana.

A patch of this plant growing under rubber was found to be badly attacked. The stems, even the smallest branches, were covered with the pink incrustation. The number of cases of pink disease on rubber on the above estate has increased considerably during the last year and there is little doubt that this patch of *Tephrosia Hookeriana* had acted as a centre of infection.

(2). Indigofera arrecta.

A patch of this plant was found to contain a few specimens attacked by Pink disease. The attack was not a severe one. The plants, as a whole were in a backward condition and it is probable that if they had been healthy the fungus would not attack them.

Indigofera sumatrana, in a plot near to the latter was growing

strongly and appeared quite healthy. This host is recorded by Rant from the Botanic Gardens, Buitzenzorg.

(3). Clitoria Cajanifolia.

This plant is also recorded by Rant as a host for Pink disease, from the Botanic Gardens, Buitzenzorg.

The form assumed by the fungus on the above plants was the pink incrustation commonly observed on rubber. Examined microscopically no trace of basidiospores was found, the incrustation being sterile as is usually the case on rubber.

THE CULTIVATION OF RICE IN SPAIN AND THE RECENT INTERNATIONAL RICE CONGRESS AT VALENCIA.

Probably few people only are aware that in the eastern provinces of Spain—particularly in the province of Valencia—the cultivation of Rice has been perfected, in certain directions, to a degree unattained in any other country in the world.

An interesting paper on the cultivation of this crop in Spain—together with an account of the congress, held at Valencia in May 1914, appears under the name of Dr. E. J. Butler—official delegate for India—in the Agricultural Journal of India Vol. IX, No. 10. The following notes are made from the information recorded therein as being of particular interest.

Spain occupies second place amongst the rice growing countries of Europe having an acreage of 98,000 acres devoted to the crop, Italy being first with 360,000 acres. One of the chief factors limiting the spread of the crop in Southern Europe is the deeply seated prejudice that Rice-cultivation and malarial fever go hand in hand.

The rice growing tracts are situated on the east coast of the country—Valencia producing three quarters of the crop—the whole area being provided with the requisite water by an highly efficient system of irrigation canals which tap the rivers Jucar and Turia.

The crop is grown in rotation with other crops.

An interesting note concerning the history of the industry is made by Dr. Butler who states:

"Though irrigation was apparently practised at the time of "the Romans, its full possibilities were not achieved until the "Moorish conquest and it is to the Moors also that the introduction "of Rice cultivation is due. It is highly probable that many of "the distinctly oriental practices followed and in particular that "of transplanting unknown elsewhere in Europe are to be traced "to the prolonged occupation of this district by an Eastern people."

The seed beds are located on land more elevated than the rice fields themselves and in one district—Alberigue—a district with a reputation as being especially suitable for the raising of seedlings, the latter are grown for export to the lower lying rice fields near the sea. These beds are manured frequently with green manures and also with heavy dressings of artificial fertilizers and are carefully "puddled" to ensure a certain degree of impermeability of subsoil prior to the seeds being sown.

The main fields are subjected to extremely thorough cultivation. They receive a first "puddling" under water in January or at such times as are dictated presumably by the condition of the water supply in the various localities, the implement used being a particularly efficient harrow which cuts and buries the weeds—here chiefly *Leersia oryzoides*—at one operation. In the case of heavy lands this operation is extended by the use of a disccutting harrow which cuts almost vertically into the soil making a series of V shaped cuts which on subsequent drying ensure an almost maximum amount of aeration.

The second operation—and the operation which is adjudged as being by far the most important—is one of dry ploughing. This is performed by means of heavy inverting ploughs whose efficiency in the industry has been proved of so great merit that it has dictated terms to the extent of bringing about a total change in the equine breed of the province. The object of this plough is to break up the land preliminary to the second puddling. This is done by the aid of special harrows a few days prior to transplantation, this latter operation being performed in the typically oriental manner, with 3″-5″ of water on the land. Six men can transplant one hectare per day.

It is a matter of some interest to find that harvest takes place while the fields are still under water. "The main rice fields are still covered with water at the time of harvest in September-October and are left to dry out gradually."

Manures are applied it would appear almost to excess, a common mixture being 600-800 lbs. per acre of sulphate of ammonia, sulphate of potash and superphosphate in the proportion per cent of 40, 6 and 54 respectively.

Guano and cyanamide are also used, the latter being at present very much boomed.

The actual cutting operation is performed with sickle and the grain usually trodden out by horses and men in a manner similar to that of the East. Threshing machines now being introduced are said to save the cost of this operation by half.

The following table is appended to this Section of Dr. Butler's paper and the figures in italics have been added thereto.

Country	Area under Rice in acres	Product in Tons	Yield per acre in lbs.
Spain	96,000	246,000	5,700
Italy	360,000	534,000	3,300
Egypt	254,000	375,000	3,300
Japan	7,393,000	7,026,000	2,100
U. S. A.	827,000	517,000	1,400
†[1]India	70,580,000	28,167,000	890
	3,010,000 hectares		
[†[2]*Java*		*4,500,000*	*1,360*
†[3]*Malaya*	*124,000 acres*	*25,000,000 gantangs at average weight (per gantang padi) of 6 lbs. = 67,000 tons approx.*	*1,210*]

Spain's preeminence over other countries in respect of yield, which—in all countries without exception—is the factor of greatest economic importance at present—prompts careful enquiry, for her method is essentially that of the East; the three following things are noted by Dr. Butler as being particularly calculated to arrest attention.

"1. The universally accepted importance of a thorough cold weather cultivation in the fields rendered possible by the use of special implements.

"2. The necessity for employing considerable quantities of suitable nitrogenous and phosphate manures.

"3. The value of introducing exotic varieties with a view to checking deterioration of races long cultivated in the same environment."

In passing we raise the query as to cost of production—the crop is five times as heavy as that obtained in this country even on a conservative estimate and we await this information with interest.

The Congress.

The subject matter discussed at the congress is fully noted by Dr. Butler from whose notes it appears that the following represent the general titles of the theses of the various Sections: Varieties and seed: Nutrition of the Rice plant: Harvest oper-

†[1] A note is added by Dr. Butler to the effect that this must be a rough average only, there being in Bengal and Madras many districts where the yield is double.

†[2] Tropen pflanzen 1912, p. 323.

†[3] Areas and products in gantangs from Report of Director of Agriculture F. M. S. for 1913.

ations machinery, etc.: Diseases of rice: The Rice market: Co-operative societies of production, etc.: Paludism and the cultivation of Rice.

Concerning the question of varieties and seed, stress was laid on the pressing need for a true botanical classification of the types of cultivated rices though it was noted that difficulties obstructing the possibility of this being an achievement of the near future were manifold and large, two in particular being noted (i) the enormity of the preliminary work involved in testing of types under the many and diverse conditions necessary ere fixity of character for classification purposes could be assumed, and (ii) the difficulties introduced into the isolation of types by the peculiarities of local nomenclature.

The procuration of organized international effort should bring good results.

A stimulating paper on the Nutrition of the Rice plant was read by Juror E. Herrero who investigated the accumulation of dry matter and the relative absorptions by the plant of Nitrogen, Potash, and Phosphorus in the three phases of its growth.

The results arrived at cannot be given in a more concise way than by the Delegate himself who states:

"The results obtained shewed that 72% of the dry matter "was found between the time of transplanting and the completion "of vegetative growth, a period of 52 days. In this period the "absorption of Nitrogen kept pace with the increase in dry matter, "the absorption of Phosphoric acid was proportionately more rapid "and that of Potash intermediate. From completion of growth to "the formation of the ear, a period of 22 days, the Nitrogen still kept "fairly parallel to the dry weight but the Potash diverged widely "reaching its maximum absorption in this period: the phosphoric "acid absorbed also considerably exceeded its proportionate quantity. "In the period, also of 22 days, from formation of ear to ripeness "the Nitrogen continued to be absorbed at a rate parallel to the "increase in dry weight but the potash falls away greatly: the "absorption of the phosphoric acid continued to increase but at a "less rapid rate now than the dry weight."

This appears to be one of the most important contributions to our knowledge governing the technique of padi manuring but from the material of the report it does not appear clear that the conclusion and its corrollary are warranted. As concerns the former "each unit of assimilating root area is called upon to provide Nitrogen at a more rapid rate in the last period of development than earlier."

This does not appear to be the case since though the roots may be developed less toward the end of development—that is toward the maturation time of the seeds—it is only necessary that they absorb a relatively smaller amount of Nitrogen as it is stated that the absorption of this element throughout the three phases runs parallel to the increase in dry weight. This latter is a quantity which from the figures quoted shews considerable decrease in the last two phases as compared with its amount in the first phase.

The congress dealt at some length with the "disease."—Brusone and results of work at Vercelli and elsewhere are indicated.

Finally it may be of interest and possibly of some relief to find recorded that the congress gave unanimity of opinion that the cultivation of Rice "modifies land subject to malaria in the direction of making it more healthy."

G. E. C.

METHODS AND MATERIALS FOR THE CONTROL OF INSECT PESTS.

PART 3.

BY P. B. RICHARDS.

CHEMICAL MEASURES. STOMACH POISONS (*continued*).

ARSENIC COMPOUNDS.

There remain to be considered only two other arsenical sprays in addition to those treated of in Part 2, namely Arsenite of Soda and Arsenious oxide. Neither of these can be used as a spray for crops on account of their solubility and consequent strong burning action on plants. Both are extremely poisonous, and under special conditions they have considerable insecticidal value.

Arsenite of Soda.

This substance has such a marked effect upon herbaceous plants that it is used as a weed killer. It is a white crystalline salt and is one of the most soluble of the arsenic salts.

Its action on plants is to kill all the green tissues with which it comes in contact. Sprayed on to grass the blades turn brown in a few hours. Any roots reached by the solution are also killed, but the quantity of solution necessary to kill all grass or lalang roots in the soil would be enormous. During wet weather the grass will grow afresh in a fortnight or three weeks.

Use.

Arsenite of soda is the most effective stomach poison for dealing with insects such as young locusts or army worm caterpillars which move slowly along the ground feeding as they go. A belt in front of or around the swarm can quickly be sprayed with this very deadly poison. The spray fluid is made as follows:—

One pound of arsenite of soda is ground into powder and mixed with five gallons of cold water. This is stirred for ten minutes, by which time the salt should be dissolved, 1½ pounds of molasses or low-grade sugar are added and the mixture is ready for use. Writing in the *Agricultural Bulletin* for May 1914 the Government Entomologist says:—"Spraying should be started in the early morning and a ring of grass, lalang, or whatever the locusts are feeding on poisoned round the swarm or in front of the direction in which they are travelling..... There are two drawbacks to the use of arsenite of soda. 1. It makes the tips of the fingers under the nails very sore..... 2. Arsenite of soda cannot be sprayed on foliage that must not be killed. It has however great advantages. First it is very effective, and secondly the fact that the grasses die very rapidly after the solution is sprayed upon them acts as a preventive to cattle grazing over the poisoned area, nor is the grass of any use for fodder."(1)

Arsenious oxide. $As_2 O_3$

Arsenious oxide is in commerce under the names arsenious acid, white arsenic, or simply arsenic. It is obtained by roasting arsenical ores.

Properties.

White arsenic is soluble in cold water in the proportion roughly, of one part by weight to one hundred parts of water. It is highly poisonous to all animals; 2 to 4 grains usually cause death in man. Its use against insects is, of course, limited by its burning action on plants. A spray containing 0·5 per cent may cause death to herbaceous plants.

Use.

White arsenic is not so satisfactory as sodium arsenite for making sprays of arsenite in solution on account of its less solubility. Its use as an insecticide is therefore confined to making poison baits for such elusive insects as surface caterpillars and mole crickets. A German Entomologist recommends to spread a mixture of white arsenic with the seeds of thyme, sweet marjoram and sweet basil in the spots frequented by mole crickets. A less delec-

(1). Locust spraying Experiments.
H. C. Pratt. Agricultural Bulletin of the Federated Malay States, Vol. 2. No. 10. May 1914.

table, but probably more effective recipe is as follows:—Mix two pounds of crude sugar, one pound of white arsenic,* and six pounds of bran with sufficient water to make a stiff paste. Place pieces the size of a walnut near the burrows or at the base of the attacked plants. This is a practicable method for the treatment of surface caterpillar (Agrotis sp:) attacks upon garden produce, having the advantage of not spreading poison over the leaves. It must not be used where poultry have access.

LEAD COMPOUNDS.

Next in importance to the arsenical insecticides rank lead compounds. One (lead arseniate) has already been considered. Of this it was said that it is by far the best of the known stomach poisons for general purposes. Its one great drawback is that it is highly poisonous to cattle and human beings. Careless application might result in accidental cattle-poisoning, and its widespread use by natives in the East, as pointed out by Maxwell Lefroy,(2) might lead to complications such as purposeful cattle-poisoning, which would be ascribed to its use as an insecticide. In the hope of finding a substitute for arsenical sprays an investigation was made at Pusa,(3) extending over several years, and covering a wide field of mineral and organic compounds, as a result of which lead chromate was selected as the standard insecticide for India. Another lead compound of insecticidal value is Red lead.

DETERRENTS.

Before describing the preparation and use of lead insecticides, a digression may be made to consider the effect of the two main classes into which stomach sprays fall. All the stomach sprays so far described are actual poisons, of which the insect swallows sufficient to cause death before discovering anything very unappetising about the food plant. The second class consists of substances which may or may not be poisonous if eaten, but which render the food distasteful to the insect, thus preventing it from feeding. Such substances are termed deterrents. If all that is required is to prevent insects from damaging particular plants, the use of a deterrent alone may be sufficient. The result of its application will be that the insects starve to death; or under stress of hunger they may return to the sprayed plants and feed in spite of the

* (Equally good results may be obtained by replacing the white arsenic with lead arseniate.)

(2). A new Insecticide, by Maxwell Lefroy, M.A. F.E.S. F.Z.S. Agricultural Journal of India, Vol. V. Part 11. April 1910.

(3). Inquiry into the Insecticidal Action of some Mineral and other Compounds on Caterpillars, by Maxwell Lefroy and H. S. Fenton. Memoirs of Dept: of Agriculture in India, Entomological series Vol. IV. No. 5.

deterrent application. Many will be destroyed during their wanderings by insectivorous birds and predaceous insects; but if suitable unsprayed food is obtainable the majority will reach maturity and carry on the attack in the next generation. It is therefore obvious that a deterrent alone is not an ideal stomach spray. Most of the actual poisons, on the other hand, are so deadly that their haphazard distribution is not advisable. The ideal stomach spray for use by other than European races should combine the protective deterrent effect with such a degree of poisoning power as would make the substance toxic to insects while not dangerous to cattle and human beings. Writing of the attempt to find such an insecticide for use in India, Maxwell Lefroy says:—"An insecticide, besides being poisonous, must have other qualities; It must be insoluble in water, not injurious to the plant, not decomposable by atmospheric influences, readily obtained in a fine state of division, and cheap. All these qualities are united with a moderate degree of poisonous effect in Lead chromate, a substance we have exhaustively tested. It is obtainable as an insoluble yellow paste which is readily sprayed on, which remains unaltered by rain or weather for a considerable time, and which is easily seen upon the plant; the paste is also very easily prepared direct in the spraying machine. Lead Chromate is the perfect substitute for arsenical poisons."(4)

Lead Chromate.

Preparation.

Lead Chromate is prepared by mixing a solution of Lead Nitrate or Acetate with a solution of Potassium Dichromate. An insoluble yellow precipitate of Lead Chromate is formed together with Potassium Nitrate or Acetate. These salts are soluble and can be got rid of by washing the precipitate with water, and filtering.

66·2 grammes of Lead Nitrate combine with 29·4 grammes of Potassium Dichromate, giving 64·6 grammes of Lead Chromate. In practice 13 parts of commercial Lead Nitrate combine with 6 parts of Potassium Dichromate, giving thirteen parts of Lead Chromate. The spray fluid may be mixed in the field and used at once, neglecting the Potassium Nitrate formed as this is not harmful to foliage in weak solutions. A convenient method for mixing is to dissolve two ounces of lead nitrate in water in the spraying machine, and one ounce of Potassium Dichromate in water in a separate vessel, and mix in the spraying machine. This gives

(4). Insecticides. H Maxwell Lefroy.
Bulletin 23. Agricultural Research Institute. Pusa.

roughly two ounces of Lead Chromate, which is sufficient for four gallons (one kerosene tin) of spray fluid at great strength, or eight gallons at normal strength.

Properties.

Lead chromate is precipitated as a flocculent yellow mass in a fine state of division. It is very insoluble in water and is harmless to vegetation. It is a slower poison for insects than Lead arseniate, possibly on account of its marked deterrent action; caterpillars may refrain from eating vegetation sprayed with the substance, but when forced to eat under stress of starvation they are poisoned.

Lead chromate is poisonous to man and cattle if eaten in considerable doses, but vegetation sprayed with a mixture containing one pound to sixty gallons is, generally speaking, innocuous. At this strength the spray poisons most leaf-eating insects. It is very adhesive, resisting rain almost as well as Lead arseniate and decomposing more slowly under atmospheric influences.

Use.

Lead chromate can be used as a spray or as a dusting powder. It is used in the manufacture of "dry paints" and is obtainable as a powder, pure or at strengths of 50% or 33%, and as a paste containing 66% of Lead chromate.

If used for dusting, one part Lead chromate is mixed with nine parts of sifted wood ashes or powdered gypsum and the powder applied while the leaves are wet with dew. This should effectively ward off insect attack from garden produce.

As a spray fluid, strengths of from one pound to thirty gallons to one pound to sixty gallons are used. It is best, if possible, to obtain the paste for field work on a large scale as this entails least labour. One and a half pounds of paste are equivalent to one pound of the pure powder. Of its use on the Experimental farm at Pusa, Maxwell Lefroy writes "We have applied this compound to a great variety of crops; we have sprayed them till every leaf was yellow; the poison has remained on for over three weeks, thickly on the leaves, which were uninjured; sprayed on to crops attacked by caterpillars, the caterpillars are killed and the results obtained have been excellent. We have used this at one pound in 32 gallons; at this strength it is extremely safe, poisons caterpillars and acts as a very powerful deterrent."

Lead Oxide. Red Lead. $Pb_3 O_4$

Red lead is another of the dry paints of considerable insecticidal value. It is a heavy powder insoluble in water and of a brilliant red colour. Its toxic properties are about the same as those of Lead Chromate, but it has less deterrent action.

Use.

Red lead is a good dusting powder for young crops and garden produce. For this purpose it should be diluted with nine times its weight of a neutral powder.

Seed beds may be protected from the ravages of seed-eating birds by mixing one ounce of red lead with a pound of seed, stirring until the seeds are uniformly red. The seed is then sown, and the birds avoid the land where the seed has been thus treated.

CARBON COMPOUNDS.

The Carbon Compounds are of more importance in the preparation of contact sprays than of stomach poisons. There are however certain substances among the carbon compounds which are valuable as actual poisons or deterrents. The more important among those are naphthalene, nicotine, and extracts of quassia and hellebore.

Naphthalene.

Naphthalene is a white scaly substance with a strong odour and bitter taste. It is insoluble in cold water and only slightly soluble in boiling water, but readily soluble in alcohol or benzene. When exposed to air, naphthalene is very volatile.

Preparation.

Naphthalene is used in the form of an emulsion. This is prepared as follows:—

Six ounces of size are dissolved in half a gallon of hot water, one pound of soft soap is stirred into this, and the solution brought nearly to boiling. As much naphthalene as the oil will absorb is dissolved in one gallon of kerosene, and the two solutions mixed and stirred together thoroughly with the addition of another half gallon of water. The use of an automatic agitator, while not necessary, renders the process of emulsification easier.

One pound of naphthalene dissolves readily in one gallon of kerosene at normal temperature. By warming the kerosene much more naphthalene is dissolved. Thus, six pounds will dissolve in one gallon of oil at 123° F and eight pounds at 140° F. A higher temperature is not safe with ordinary methods for heating. The heating should not be done over a fire, but by placing the vessel containing the kerosene into another with hot water. The more naphthalene there is in the emulsion, the better.

The spray-fluid is made by mixing this stock solution with water so that twenty gallons of spray-fluid contain one pound of naphthalene.

Properties.

Naphthalene emulsion at the above strength has some poisonous effect on small caterpillars but does not kill large ones. It is, however, a powerful deterrent, the insects refusing to feed so long as any naphthalene remains. One day of hot sun is sufficient for the volatilisation of the naphthalene; at the longest it will all have evaporated in three days. The emulsion has no effect upon the plants, which are left free from poison or unpleasant taste. It is thus an ideal spray for treating vegetables intended for immediate consumption, but is of no use as a general insecticide.

Use.

The spray fluid should be applied in a fine misty spray in the evening of alternate days, or every day if there is very hot sun.

(Alkaloid infusions will be considered next month.)

TROPICAL AGRICULTURE.

The Proceedings of the Third International Congress of Tropical Agriculture, which have just been published (London: John Bale, Sons and Danielsson, 10*s*. net), form a substantial volume of over 400 pages. The volume is edited by the Honorary Secretaries of the Congress, which, it will be remembered, was held last June at the Imperial Institute. This was the first time the Congress had been held in London, and the result was most successful. More than 150 papers, coming from authorities in fifty different countries, were presented to the Congress, and important discussions took place on several of the principal problems connected with tropical agriculture. Abstracts of the papers and full reports of the discussions are printed in the "Proceedings," together with the address delivered by the President of the Congress, Professor Wyndham R. Dunstan, C.M.G., LL D., F.R.S., Director of the Imperial Institute, and President of the International Association for Tropical Agriculture.

Amongst the subjects dealt with in the Proceedings are Technical Education in Tropical Agriculture; Organisation of Agricultural Departments in Relation to Research; Agricultural Credit Banks and Co-operative Societies; Sanitation and Hygiene on Tropical Estates; Legislation against Plant Diseases and Pests; Fertility of Soils in the Tropics; Variation in Plantation Rubber; Cotton and Cotton Cultivation; Jute and Hemp Fibres; Cereals; Sugar; Cocoa; Tobacco; Oils and Oil Seeds.

The speakers taking part in the discussions included the Right Hon. Lewis Harcourt, M.P. (Secretary of State for the

Colonies), Earl Kitchener, the Earl of Derby, Lord Emmott, Sir George Reid, Sir Hugh Clifford, Sir Horace Plunkett, Sir Ronald Ross, Sir H. Hesketh Bell, Sir Sydney Olivier, Sir E. Rosling, and a host of authorities on tropical agriculture from all over the world.

This book thus forms a valuable record of expert opinion on all the more important problems of Tropical Agriculture and Colonial Development, which at the present time are of particular interest.

FEDERATED MALAY STATES.

Comparative Statement of Cultivated Rubber Exported, with Value and Duty Collected Thereon, during the Years 1914 and 1913.

Destination.	Exported during Dec., 1914.	Previously.	Total export during the year.	Export during similar period of previous year.	Increase.	Decrease.	Value of rubber exported, 1914.	Duty collected, 1914, to date.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	$	$ c.
Straits Settlements ...	1,794.48	16,050.46	17,844.94	10,941.23	6,903.71	...	29,536,447	
United Kingdom ...	1,506.11	9,746.81	11,252.92	10,505.74	747.18	...	22,107,314	
Continent of Europe ...	...	807.78	807.78	1,401.02	...	593.24	1,437,762	
Ceylon	60.69	630.89	691.58	617.85	73.73	...	1,030,944	
Other Countries ..	...	100.27	100.27	...	100.27	...	413,498	
Total ...	3,361.28	27,336.21	30,697.49	23,465.84	7,824.89	593.24	54,525,965	1,334,244.92

KUALA LUMPUR,
19th August, 1915.

F. J. WELD,
Acting Commissioner, Trade and Customs, F.M.S.

Abstract of Meteorological Readings in the various Districts of Malaya for the Month of December, 1914.

DISTRICT.	Mean Barometrical Pressure at 32° Fah.	Maximum in Sun.	TEMPERATURE.				HYGROMETER.				Prevailing Direction of Winds.	Total Rainfall.	Greatest Rainfall during 24 hours.
			Mean Dry Bulb.	Maximum.	Minimum.	Range.	Mean Wet Bulb.	Vapour Tension.	Dew Point.	Humidity.			
Kelantan, Kota Bahru	...	145.	79.4	87.12	73.64	13.48	77.1	.883	75.5	88%	...	17.82	1.79
Malacca, Durian Duan Hos.	29.799	151.9	82.5	87.5	71.2	16.3	78.9	.971	—	87	N.	9.93	2.55
N. Sembilan, Dist. Hospital Seremban	...	147.5	79.2	86.6	72.4	14.2	76.0	.842	74.0	83	N.W	10.61	1.93
,, Dist. Hos. K. Pilah	...	156.5	82.1	89.0	73.2	15.8	78.7	.923	76.5	83	...	9.41	2.00
,, ,, Tampin	...	140.3	79.5	90.0	73.4	16.6	76.6	.846	74.1	81	...	5.90	0.80
,, ,, P. Dickson	...	126.7	81.5	86.9	74.1	12.8	77.4	.862	74.7	80	...	10.69	2.95
Pahang, ,, K. Lipis	...	...	79.7	87.5	71.2	16.3	75.6	...	...	...	...	10.14	1.85
Penang, ,, Penang	29.825	140.9	82.3	88.3	73.6	—	77.5	.826	74.9	80	...	6.16	1.40
Perak, ,, Taiping	...	...	81.09	94.	69.	25.	77.34	.889	...	85	...	22.30	2.60
,, ,, Ipoh	...	...	81.72	95.	71.	24.	76.92	.862	...	80	...	14 20	1.97
,, ,, T. Anson	...	...	82.05	94.	71.	23.	77.51	.883	...	81	...	8.35	1.53
,, ,, P. Buntar	...	...	81.27	92.	73.	19.	76.82	.865	...	82	...	8.22	1.38
,, The Cottage	...	...	...	..	...	...	...	...	...	...	...	28.75	3.27
Selangor, General Hospital Kuala Lumpur	...	145.0	80.3	88.1	...	...	77.2	.877	75.2	84	Calm	10.34	2.20
,, Dist. Hos. Klang	...		81.1	87.7	73.2	14.5	79.7	...	...	...	...	7.49	1.40
,, ,, K. Selangor	...	...	...	87.3	75.6	11.7	...	...	...	...	...	2.94	0.48
,, ,, Rawang	...	...	...	91.6	71.9	19.7	...	...	...	...	...	14.29	3.21
Singapore Kandang Kerbau Observatory	29 830	163.4	81.9	87.8	74.9	12.9	77.6	.887	...	81		7.37	2.04

Abstract of Meteorological Readings in the various Districts of Malaya for the Month of November, 1914.

DISTRICT.	Mean Barometrical Pressure at 32° Fah.	Maximum in Sun.	Temperature.				Hygrometer.				Prevailing Direction of Winds.	Total Rainfall.	Greatest Rainfall during 24 hours.
			Mean Dry Bulb.	Maximum.	Minimum.	Range	Mean Wet Bulb.	Vapour Tension.	Dew Point.	Humidity.			
Kelantan, Kota Bahru	...	149.	80.5	87.83	74.16	13.66	77.6	.885	75.6	85%	...	13.55	4.25
Malacca, Durian Duan Hos.	29.790	153.7	83.9	88.7	72.	16.7	79.5	.964	...	84	N.	10.69	1.84
N. Sembilan, Dist. Hospital Seremban	...	149.3	78.8	87.2	71.8	15.4	75.9	.841	73.9	84	N.W.	9.18	1.48
,, Dist. Hos. K. Pilah	...	...	81.0	89.4	73.2	16.2	77.7	.889	75.5	83	...	5.52	1 82
,, ,, Tampin	...	144.5	80.9	90.6	75.2	17.4	76.8	.841	73.9	79	...	13.18	2.36
,, ,, P. Dickson	...	...	81.6	87.3	75.8	13.5	77.4	.857	74.5	79	...	10.26	2.35
Pahang, ,, K. Lipis	...	...	81.0	89.2	71.3	17.9	76.2	...	...	...	...	7.59	2.75
Penang, ,, Penang	29.816	141.9	82.3	88.6	73.2	...	77.6	.874	74.9	81	...	11.31	4.10
Perak, ,, Taiping	...	...	81.09	92.	68.	24.	76.82	.867	...	82	...	37.12	4.93
,, ,, Ipoh	...	...	81.98	92.	70.	22.	76.90	.858	...	78	...	15.89	2.48
,, ,, T. Anson	...	...	81.93	92.	70.	22.	77.52	.886	...	83	...	21.97	3.15
,, ,, P. Buntar	...	...	81.75	91.	71.	20.	77.39	.875	...	83	...	13.14	2.13
,, The Cottage	...	...	...	...	...	...	...	...	...	...	...	34.27	5.00
Selangor, General Hospital, Kuala Lumpur	...	145.5	80.1	88.8	...	...	77.0	.868	74.9	84	N.E.	17.03	2.05
,, Dist. Hos. Klang	...	...	80.4	87.9	73.3	14.6	78.8	...	...	...	...	12.47	2.27
,, ,, K. Selangor	...	...	...	87.5	75.1	12.4	...	...	...	...	...	9.97	3.58
,, ,, Rawang	...	...	...	92.0	71.9	20.1	...	...	...	...	...	11.42	2.74
Singapore, Kandang Kerbau Observatory	29.809	162.2	82.8	89.0	74.7	14.3	77.9	.885	...	79	...	6.93	1.93